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EVALUATION OF ULTRAHIGH VACUUM WITH FIELD-EMISSION MICROSCOPE (POLAND)

Translation

AID Work Assignment No. 43
Task 20

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EVALUATION OF ULTRAHIGH VACUUM WITH FIELD-EMISSION MICROSCOPE (POLAND) (*)

This translation was prepared in response to AID Work Assignment No. 43, Task 20. The article was originally published as follows:

Lenkow, Wojciech, and Czeslaw Workowski, Department of Experimental Physics of Wroclaw University. Przeglad elektroniki, v. 3, no. 11, 1962, 646-648.

A possibility of considerable reduction in the adsorption time of gas residue in the tungsten emitter of a Müller microscope was demonstrated by applying electric sorption.

A 700-fold acceleration in the adsorption time permits a comparative measurement of the total pressure of active gases of the order of 10^{-11} tor [mm Hg] in less than 100 sec. The possibility of applying this method to measuring pressures in the range of 10^{-8} to 10^{-14} mm Hg is anticipated.

Difficulties connected with measuring a vacuum of the order of 10^{-10} mm Hg and of more perfect ones through the use of conventional methods resulted in the consideration of the possibility of applying Müller's microscope for measuring a vacuum in this range of pressures.

The Müller field emission microscope is a kind of vacuum tube in which the cathode consists of a tiny monocrystal point placed at the top of a metal or semiconductor point.

In fields of the order of 10^8 v/cm an electron field emission appears, and the emission current density, due to the anisotropy of the work function, is a function of crystallographic direction. On a luminescent screen-anode surrounding the tip one obtains an electronic image which constitutes a kind of stereographic projection of the emitting crystal.

By using point emitters made of high-temperature metals (tungsten, molybdenum, tantalum, rhenium) it is easy to obtain a clean emitting surface in a good vacuum by annealing at high temperatures.

Any sorption processes occurring on the emitter surface cause a change in the work function of the individual crystal walls. This results in the formation of characteristic change in the

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(*) This paper was presented for the first time at the Convention of Polish Physicists on September 17, 1961.

emission image and in a change of the total field emission current in accordance with the Fowler-Nordheim relation, which establishes the first approximation of a description of the field emission phenomenon

$$I = AE^2 e^{-\frac{C\varphi^{3/2}}{E}}, \qquad (1)$$

where I is the density of emission current,
E is the electric field intensity near the emitter surface,
A is a magnitude loosely dependent on the work function, which in this case can be considered as a constant,
φ if a constant equal to $6.7 \cdot 10^7$,
C is the work function of the emitter.

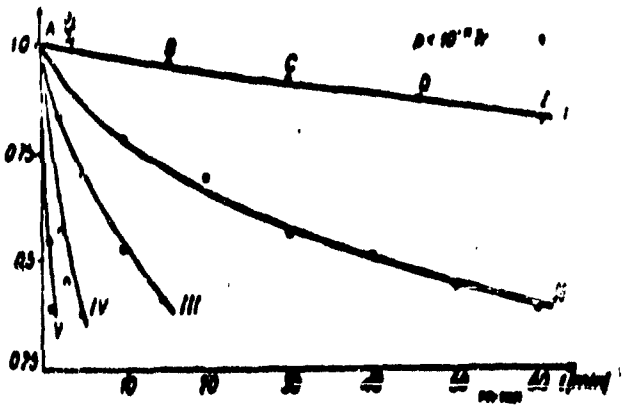

Fig. 1. Curves of decay of field emission for various initial emission currents. Curve I for I = 0; curve II for $I = 10^{-8}$ amp; curve III for $I = 5 \cdot 10^{-8}$ amp; curve IV for $I = 3 \cdot 10^{-8}$ amp; and curve V for $I = 1 \cdot 10^{-8}$ amp

Curve I of Fig. 1 represents a change in the field emission current caused by adsorption processes occurring on the emitter. At the moment t equals 0 one is dealing with a clean emitter surface; at point A an electric field was applied for a few seconds selected in such a way that the emission current would equal 10^{-7} amp. The adsorption process was conducted without an electric field, with the exception of points B, C, and D in which a field of the same value as in point A was applied. The gradual decay of emission current illustrates the increase of the diameter of the emitter work function.

There have been attempts to utilize this phenomenon for an evaluation of the vacuum [3,4]; however, considering the

long adsorption time of gas residues in more perfect vacuums (the time of formation of a monomolecular layer in a 10^{-11} mm Hg vacuum is of the order of 10^{3} sec), this method did not find wider acceptance.

An investigation of gas residues on a tungsten emitter, in vacuums nonmeasurable with the classical vacuum meter of Bayard-Alpert, revealed an acceleration of adsorption when this process was occurring in such strong electric fields that the cold emission current was of the order of several μa.

A closer investigation demonstrated that the initial emission current had a significant effect on the speed of adsorption of gas residues (the initial current is the current emitted by a clean point at a certain field value fixed for the time of measurement). The effect of the electric field itself on the process was found to be relatively small.

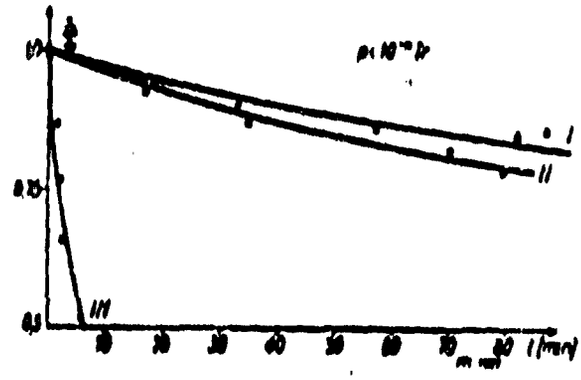

Fig. 2. Curves of decay of emission current: without a field, in a reverse field (+ on the point), and in uniform field (- on the point); the horizontal axis is time in minutes; the vertical axis is the ratio $\frac{I_t}{I_0}$

Fig. 2 illustrates the effect of these two quantities in accelerating adsorption. Curve I shows the decay of emission from a point under normal conditions (without a field), curve II illustrates an identical decay for an emitter in a field with $2.6 \cdot 10^{7}$ v/cm intensity and directed in such a way that there is no field emission of electrons, and finally, curve III shows the same process in a field with a $2.6 \cdot 10^{7}$ v/cm intensity and with 10^{-8} amp of initial current.

Without entering as yet into explanations of the mechanism of this phenomenon which, no doubt, depends on electric

sorption of positive ions, polarized by the field of atoms and particles on the cleaned surface of the emitter, one can ascertain that its presence creates certain new possibilities in the field of measurements of low pressures. The 700-fold reduction of the time of adsorption attained by the authors with an emission current of 10^{-4} amp (Fig. 1) permits an evaluation of pressures of the order of 10^{-11} mm Hg in a time of less than 100 sec. Certain experimental data exist [5,6] which permit the belief that, in vacuums of the order of 10^{-13} mm Hg, one may be able to obtain an acceleration of the order of 10^{3} times in adsorption time which would permit an evaluation of a vacuum 2 to 3 times more accurately.

Introductory experimental data indicate that the highest pressures of gases subject to electric sorption which can be measured by this method lie within the limits of 10^{-7} to 10^{-8} mm Hg.

Experiments designed to explain these processes of electric sorption and to give a more detailed determination of conditions for applying the described method are being continued. Results will be published as further progress is achieved.

The authors thank Professor Jan Nikliborc, of whose experience and friendly help they had several times availed themselves.

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